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GB 0631988 A

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(54) Pipeline condition monitoring system and apparatus

(57) A pipeline cleaning pig is provided with sensing means formed and arranged for detecting, directly or indirectly the effect of pipeline conditions on the passage of the cleaning pig such as sensing debris deposits dents, bends, corrosion, leaks, blocks, valve positions along the pipeline, and data storage means (preferably mounted on-board) formed and arranged for receiving and storing data from the sensing means so as to record a continuous condition profile for the length of pipeline. The pig has cleaning flanges 40 and a pressure container 20 with the sensing means, data storage means and a power supply. Pressure differential is detected by forward and rear probes 32, 36.

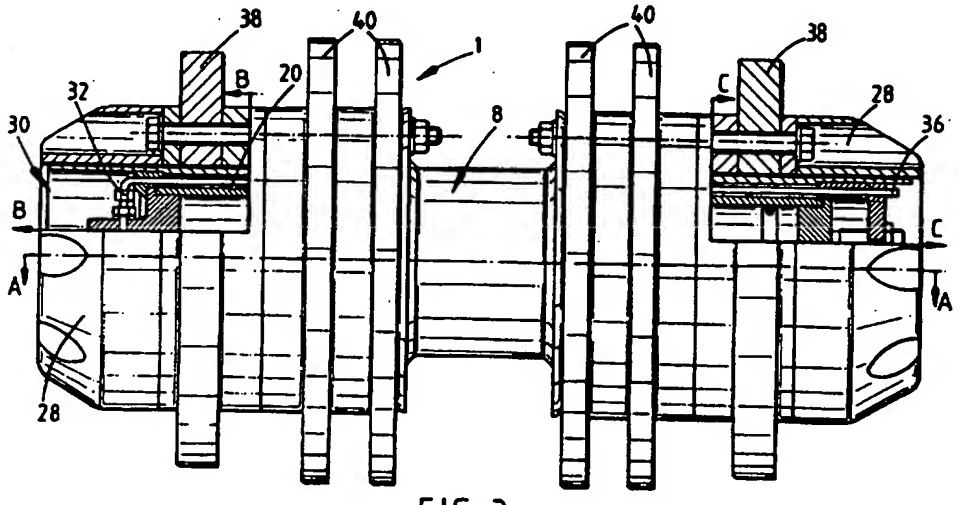

FIG.3

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

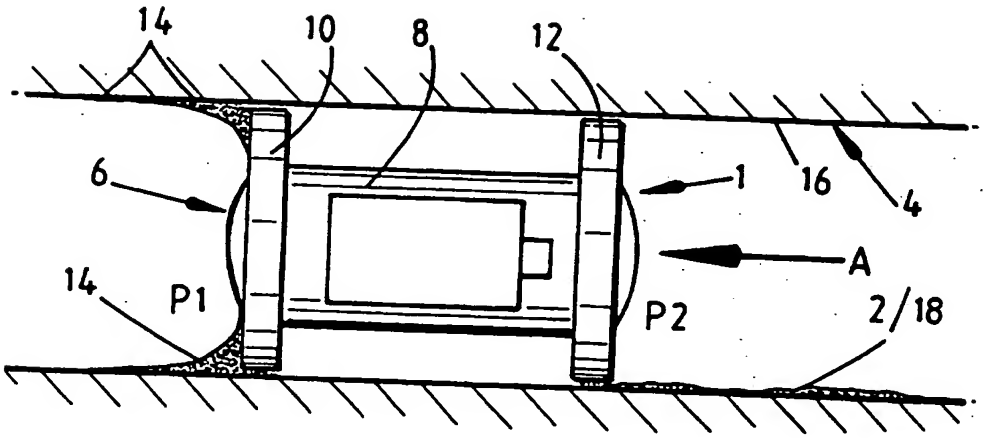
14
10
8
12
6
1
16
4
A
14
P1
P2
2/18

FIG. 1

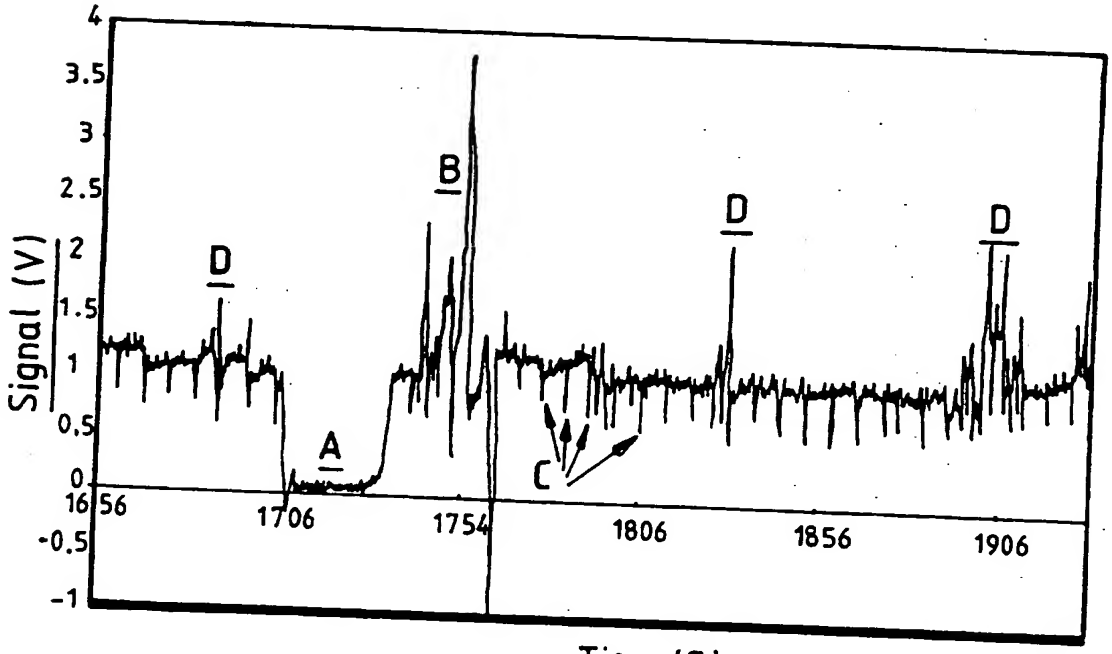
Signal (V)
4
3.5
3
2.5
2
1.5
1
0.5
0
-0.5
-1
D
A
B
C
D
D
16 56
1706
1754
1806
1856
1906
Time (S)

FIG. 2

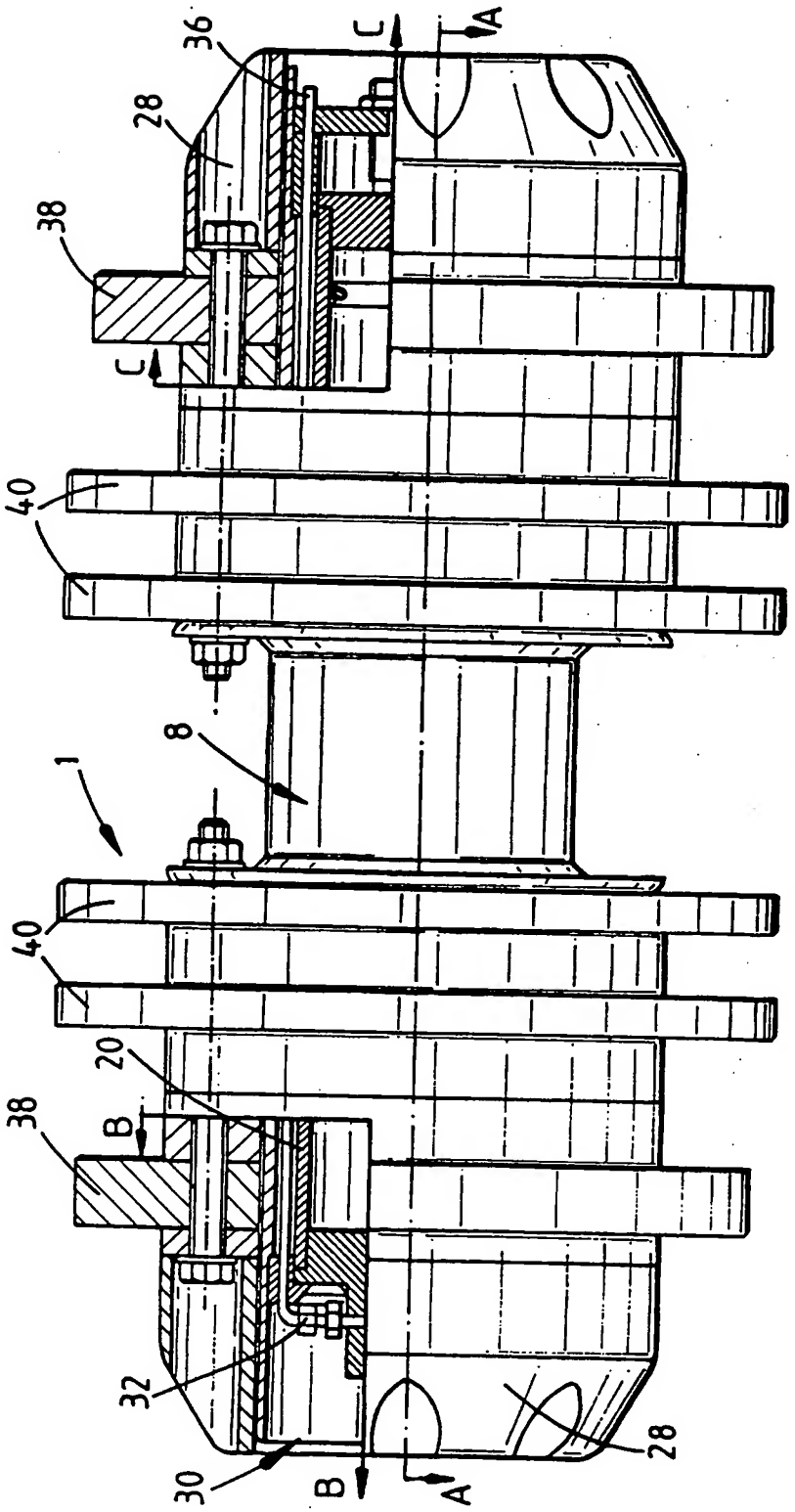

FIG.3

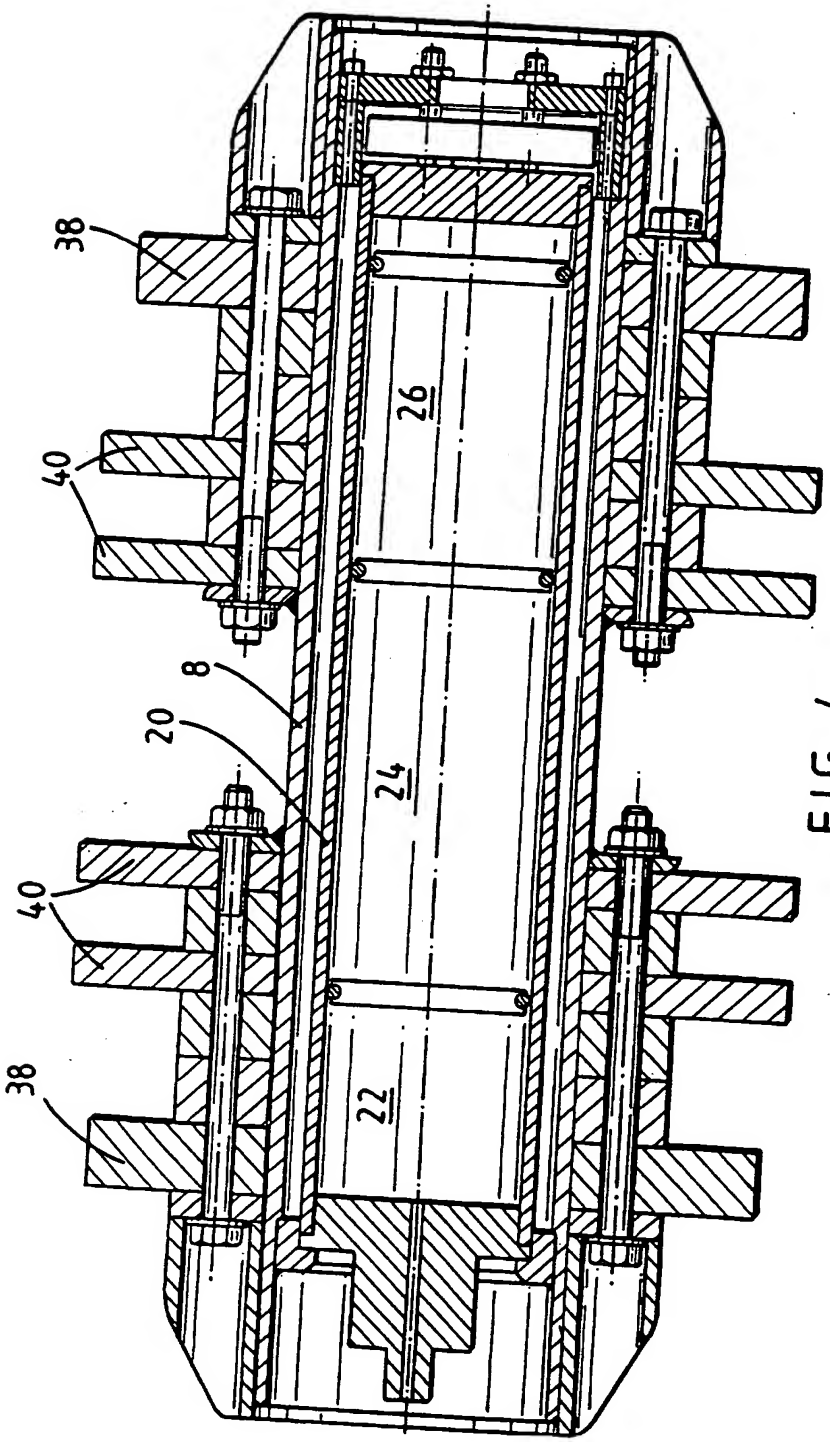

FIG.4

PIPELINE CONDITION MONITORING SYSTEM and APPARATUS

The present invention relates to a pipeline condition monitoring system and apparatus for obtaining a pipeline condition profile or survey prior to "intelligent pig" inspection techniques. The present invention relates also to a debris monitoring system and apparatus for use in monitoring internal debris deposits in pipelines and for obtaining a debris deposit profile for a length of pipeline, in particular oil and gas pipelines, prior to pipeline integrity monitoring and inspection using "intelligent pig" inspection techniques.

The safe and continuous operation of hydrocarbon pipeline networks are essential to the operators and users of such networks and to national economies served by such networks. Accordingly such pipelines are cleaned and inspected at regular intervals to ensure their operational integrity. The conventional approach to inspection of pipelines is for the pipeline to be cleaned several times using a "dumb" pig so as to scrape and remove debris such as wax, scale, sand and other foreign matter from the pipeline whilst maintaining fluid supply via the pipeline, prior to closing down the fluid supply and detailed inspection by an "intelligent pig" using complex tools generally comprising arrays of probes and sensors and techniques such as magnetic flux leakage (MFL) or ultrasonic scanning to detect flaws or defects which might prejudice the pipeline's integrity. Examples of pigs are given in the UK Patent Office monograph

on pipeline pigs.

It has been found, though, that many cleaning pigs simply fail effectively to clean a pipeline at all points therealong and thus when an intelligent pigging operation is undertaken the results obtained may be inaccurate, misleading or useless because the pipeline is not clean and that the measurements have been distorted as a result. Such intelligent pigging operations typically cost in excess of £100,000 and thus it will be appreciated that is highly desirable that the information and data obtained should be as accurate and reliable as possible in order to avoid unnecessarily wasted expense and lost production time, and the risk of pipeline integrity failure not being detected. Furthermore the information and data obtained from intelligent pigging techniques can be enhanced and interpreted more accurately if some basic information about the condition of a pipeline to be measured is available. The sort of information that can be useful and complementary to intelligent pigging techniques is basic information about the "condition" of a pipeline therealong in the sense of the presence of any factors which could indicate the need for intelligent pigging surveying, distort intelligent pigging measurements etc. etc., such as internal corrosion thereof; pipeline spanning (where pipelines sag due to the removal of support therefrom e.g. through washing away of the seabed underneath a pipeline due to the effect of sea currents); dents; presence of flange or other connections; valve positions (fully or partly open/closed); bends and the

position of such and other pipeline conditions and features.

Conventional debris monitoring techniques have focused on sampling debris directly at pre-determined intervals only along a pipeline, however the types and composition of debris, even after cleaning, can vary considerably along a pipeline and thus some debris deposits may be missed altogether. Accordingly the confidence level of the accuracy of data obtained by intelligent pigging operations undertaken after cleaning has not been significantly improved. Conventional techniques for measuring or monitoring pipeline conditions such as corrosion etc. have required the use of the abovementioned very expensive intelligent pigging techniques and it would be economically desirable to obtain a pipeline profile as part of the normal cleaning strategy before adopting such intelligent pigging techniques.

It is an object of the present invention to avoid or minimise one or more of the foregoing disadvantages.

It has now been found that the efficiency and effectiveness of intelligent pigging operations can be improved by carrying out a simpler "passive" sensing survey of the pipeline, which may even be incorporated into a conventional cleaning pig and used without disrupting the fluid supply through the pipeline, to obtain a profile of the pipe condition (in one or more respects such as debris deposition, corrosion etc.), prior to conducting an

intelligent pigging survey. Of course in some cases such a pipe condition profile may be useful in itself e.g. in determining whether or not any intelligent pigging is required, i.e. without the need for a subsequent intelligent pigging survey.

Thus in one aspect the present invention provides an apparatus for use in obtaining a substantially continuous pipeline condition profile for a length of pipeline which apparatus comprises a cleaning pig provided with sensing means formed and arranged for substantially continuously, directly or indirectly, sensing changes in pipeline condition along a said length of pipeline, and data storage means (preferably on-board) formed and arranged for receiving and storing data from said sensing means thereby to record a pipeline condition profile for said length of pipeline.

In a second respect the present invention provides an apparatus suitable for use in obtaining a substantially continuous debris deposit profile for a length of pipeline which apparatus comprises a debris sensitive pipeline pig provided with sensing means formed and arranged for substantially continuously, directly or indirectly, sensing debris deposits along said pipeline, and data storage means (preferably on-board) formed and arranged for receiving and storing debris deposit data from said sensing means thereby to record a substantially continuous debris deposit profile for said length of pipeline.

Thus with an apparatus according to the present invention the substantially continuous pipeline condition profile or debris deposit profile obtained therefrom may be correlated with data obtained from intelligent pigging operations so as to obtain a reliability profile for the pipeline integrity data and/or compensate the pipeline integrity data for anomalies resulting from the presence of debris deposits or other pipeline conditions or features which have affected in one way or another the passage of said pig along said length of pipeline.

Thus in a third respect the present invention provides a system for measuring pipeline integrity comprising an apparatus for obtaining a substantially continuous pipeline condition, e.g. debris deposit, profile for a length of pipeline; an intelligent pig for measuring pipeline integrity along said length of pipeline; and algorithm means for quantitatively determining the reliability of pipeline integrity data measurements and/or compensating the pipeline integrity data for anomalies resulting from the pipeline condition along said length of pipeline.

In a fourth respect the present invention also provides a method of establishing the integrity of a length of pipeline comprising the steps of:

- obtaining a substantially continuous debris deposit or other pipeline condition profile for said length of pipeline;
- taking measurements at a multiplicity of points along a

said length of pipeline using an intelligent pigging process for monitoring the integrity thereof;

- processing said measurements of the integrity of said pipeline with the aid of said substantially continuous debris deposit profile or other pipeline condition profile for at least one of obtaining a reliability profile for the pipeline integrity data and/or compensating the pipeline integrity data for anomalies resulting from the presence of debris deposits or other pipeline conditions along said length of pipeline.

In a fifth respect the present invention provides a method of obtaining a substantially continuous debris deposit profile for a length of pipeline comprising the steps of:

- providing a debris deposit sensitive pipeline pig having sensing means for directly or indirectly sensing the presence of debris deposits;
- passing said debris deposit sensitive pipeline pig through a length of pipeline to sense substantially continuous debris deposits therealong; and
- collecting data obtained by said sensing means so as to obtain a substantially continuous debris deposit profile for said length of pipeline.

Preferably said sensing means is formed and arranged for sensing both qualitatively and quantitatively the presence of debris deposits or other pipeline conditions.

In a sixth respect the present invention provides a method

of obtaining a substantially continuous condition profile for a length of pipeline comprising the steps of:-

- providing a pipeline pig having passive sensing means formed and arranged for sensing the effect of pipeline condition on the passage of said pipeline pig as it passes therealong;

- passing said pipeline pig through a length of pipeline; and

- collecting data obtained by said passive sensing means so as to obtain a pipeline condition profile for said length of pipeline.

As used herein the expression "passive" sensing means indicates sensing means which simply record physical effects associated with the passage of the pipeline pig such as changes in pressure, speed, acceleration, noise, temperature etc. as opposed to "active" sensing as used in intelligent pigging techniques which probe the pipeline e.g. with radiation, sound waves etc.

It will be appreciated that the term "pipeline condition" may embrace a variety of different and independent pipeline factors such as debris deposits the combination of which will provide an overall pipeline condition profile. Certain pipeline condition factors will be known or will be readily recognisable in a pipeline condition profile such as for example the flange joints between sections of pipeline which will show up on a pipeline condition profile as a series of regularly spaced features. Such known features

may be removed so as to leave a profile of other pipeline conditions. Other pipeline conditions which might be sensed apart from debris deposits include areas on the inside surface of the pipeline where there is corrosion; partial blockages inside a pipe; leaks from a pipe; damage to pipe cladding; changes in the position of a pipeline or a section of a pipeline for example due to spanning; dents or bends in a pipeline as a result of external damage; and open/closed valves. The aforesaid examples of pipeline conditions will each exhibit a particular data signature(s) the combination of which will make up the complete pipeline profile. The data comprising the complete pipeline profile may then be interpreted using artificial intelligence techniques such as artificial neural networks.

Preferably said debris sensitive pipeline pig is in the form of a pipeline cleaning pig or "dumb" pig of generally known type and construction e.g. a disc or cup pig or a foam swab pig provided with a sealed pressure vessel contained therein formed and arranged for containing debris deposit profile data or other data collection means and any on-board data storage means. Desirably there is provided on-board data processing means also contained within said pressure vessel for performing at least some processing of data obtained from said sensing means. Alternatively said on-board data storage means and/or data processing means may be replaced with data transmission means for transmitting data obtained from said sensing means to remote data storage and processing means such as artificial neural networks. There

is also provided a suitable power supply means in said pipeline pig, desirably in said pressure vessel, for powering at least one of said on board data storage means, data processing means and said data transmission means.

Various forms of sensing means may be utilised and in the simplest form of the apparatus of the invention a single sensing means is used. Preferably though a plurality of different sensing means are employed. Suitable sensing means may be formed and arranged for detecting one or more parameters associated with interaction of the debris sensitive pipeline pig with debris deposits and/or the passage of the pig in the pipe, as it passes along the length of pipeline and is perturbed by debris deposits or other pipeline conditions, such as:

- differential pressure across said pig between a leading end and a trailing end thereof;
- velocity of said pig as it passes along a length of pipeline;
- longitudinal, and optionally angular, acceleration and deceleration of said pig as it passes along a length of pipeline;
- vibrations;
- noise (including amplitude and/or frequency characteristics thereof) generated by interaction of the pig with the wall of the pipeline and/or deposits thereon or other pipeline conditions;
- temperature gradients and variations; and
- friction between the pig and the pipewall.

Such parameters can be used to provide information on conditions in the pipeline such as cracks, pits, corrosion, wall thinning spanning, dents or other flaws. Once such conditions have been identified expensive and highly complex intelligent pigging techniques, of generally known type and construction can be used in order to obtain qualitative and quantitative information thereon.

Alternatively or additionally the debris sensitive pipeline pig could be provided with sensor systems formed and arranged for sensing the presence of debris independent of any direct physical interaction between the debris sensitive pig itself and the debris. Thus for example there could be provided non-contact, active, sensing means capable of sensing debris without relying on any physical interaction between the pig itself and the debris e.g. ultrasonic probe means or radiation sensing means for detecting radiation associated with the debris.

Preferably there is provided distance measuring means such as an odometer wheel on said pig for detecting the distance travelled by said pig. Desirably though said apparatus is provided with timing means. Pipelines are generally made up of a plurality of fixed lengths of pipe e.g. 12m, 6m or 3m. Said sensing means, particularly where differential pressure sensing means are used, can detect the flange or welded joint where two lengths of pipe are connected together so that by detecting said flanges/welded joints the position and speed of travel of the apparatus of the invention along

a pipe may be determined and such information used to assist in providing said debris deposit profile.

The apparatus may also be provided with a gyroscope to give information about the orientation of the apparatus in a pipeline such that nosing/tipping or skewing of the apparatus due to highly localized debris deposits; dents; patches of internal corrosion or other changes in the physical characteristics of the pipeline may be detected, and/or the position of changes in direction of the pipeline recorded.

It will be appreciated that the condition of a pipe and the debris therein will change over time and that a pipeline condition profile obtained for a given length of pipeline with exhibit a different profile from a profile taken some time earlier (or later). It will be understood therefore that by comparing two profiles for a given length of pipeline obtained at separate times, (usually as part of the normal pipe cleaning schedule) it is possible to give an advance warning of a change(s) in pipeline conditions and/or pipeline integrity failure which may be examined in more detail using intelligent pigging techniques.

Further preferred features and advantages of the present invention will appear from the following detailed description given by way of example of a preferred embodiment illustrated with reference to the accompanying drawings in which:-

Fig. 1 is a schematic side view of an apparatus according to the present invention;

Fig. 2 is a graph of the output from the apparatus shown in Fig. 1 in use on a test rig;

Fig. 3 is a side view of an embodiment of the invention; and

Fig. 4 is a section plan view of the embodiment in Fig. 3.

Reference is first made to Fig. 1 which shows an apparatus of the invention, generally indicated by reference number 1, suitable for use in obtaining a debris deposit 2 profile for a length of pipeline 4. The apparatus 1 comprises a debris sensitive pipeline cleaning pig 6 having a casing 8 mounted on and between two spaced apart guides 10, 12.

The guides 10, 12 have a diameter slightly less than the internal diameter of the pipeline 4 and act as scrapers to clear away debris 14 on the inside wall 16 of the pipeline 4 as the pig 6 passes through the pipeline 4 in the direction of arrow 'A'. The difference in pressure of the liquid in the pipe across the pig 6 indicated by 'P1' and 'P2' drives the pig 6 along the pipeline. Once the cleaning pig 6 has passed through the pipe a certain amount of residual debris 18 is left behind. It is the amount and location of this residual debris 18 which is qualitatively and quantitatively measured using the apparatus of the invention to obtain a debris deposit profile for the length of pipeline.

Mounted within the casing 8 (shown in more detail in Figs. 3

and 4) are on-board data storage and processing apparatus for measuring, in this example, the differential pressure across the pig 6. The pig 6 is provided with pressure sensors (not shown) for measuring the pressure 'P1' at the leading end of the pig and the pressure 'P2' at the trailing end of the pig 6.

Fig. 2 shows a graph of the change in differential pressure across the pig, measured as a voltage, as it travels around a test rig pipeline against time.

At point A on the graph, the pig is stationary and experiences no pressure differential. As fluid in the pipe starts to flow the pig experiences a pressure which drives it along the pipe. At point B the pig passes through a valve change over point in the pipe and experiences large pressure transients. The pig then settles down and passes over joints in the pipe which are indicated by the downward spikes C on the graph, at regular spaced apart 6m intervals. As the pig passes along the pipeline it experiences changes in the internal debris and changes in the direction of the pipeline and the pipe joints etc which are indicated by transient pressure spikes D. As information and data about the pipe joint intervals, directional changes in the pipeline, valve change over points etc. are known for a given pipeline system then this data may "removed" by processing from the differential pressure data obtained by the pig to give a debris deposit profile for the given pipeline system.

Figs. 3 and 4 show in more detail a preferred embodiment of the apparatus of the invention. The casing 8 of the apparatus 1 is in the form of a hollow pressure vessel 20 (see also the section along line A-A in Fig.4) which houses instrumentation 22 for measuring, in this embodiment, the pressure differential across the pig 6; a processor 24 for processing and storing data obtained from the instrumentation 22; and a power supply in the form batteries 26 for supplying power to the instrumentation 22 and the processor 24. The pressure vessel is securely held inside the pipeline pig by end plate 28 bolted to the main body of the pipeline pig.

The leading end 30 of the pipeline pig 6 (shown in part section along line B-B) is provided with a first pressure sensor 32. The trailing end 34 of the pipeline pig 6 (shown in part section along line C-C) is provided with a second pressure sensor 36. Each of the first and second pressure sensors 32, 36 are connected to the instrumentation 22 so that the pressure differential across the pipeline pig may be readily calculated by the processor 24.

The other external features of the debris sensitive pipeline pig 6 are generally similar to known constructions of dumb cleaning pipeline pigs having two spaced apart guides 38, whose diameter is generally somewhat less than the internal diameter of the pipeline to be cleaned; and four spaced apart cleaning seals 40. The cleaning seals 40 have a diameter generally greater than the internal diameter of the

pipeline to be cleaned and are made of resilient materials so that in use inside a pipeline the peripherary of the seal is deflected into a sealing engagement with the inside wall of the pipeline.

Various modifications may be made to the above described embodiment without departing from the scope of the present invention. Thus for example there may be provided on the apparatus between the spaced apart guides a probe formed and arranged for contact with the inside wall of the pipeline and for measuring the friction between the pipeline pig and the inside of the pipeline and thereby to obtain debris deposit profile for the length of pipeline being measured.

The embodiment described hereinbefore and with reference to the accompanying drawings Figs. 1 to 4 teaches of a debris sensitive pipeline cleaning pig. It will be appreciated that the cleaning pig may be provided with other sensing means formed and arranged for detecting what effect other pipeline conditions and/or features such as dents, bends, spanning, corrosion, leaks, blocks, valve positions, flange connections etc. have on the passage of the cleaning pig through a pipe.

CLAIMS

1. An apparatus for use in obtaining a substantially continuous pipeline condition profile for a length of pipeline which apparatus comprises a cleaning pig provided with sensing means formed and arranged for substantially continuously, directly or indirectly, sensing changes in pipeline condition along a said length of pipeline, and data storage means formed and arranged for receiving and storing data from said sensing means thereby to record a pipeline condition profile for said length of pipeline.

2. An apparatus according to claim 1 wherein said data storage means are provided on board said pipeline pig.

3. An apparatus according to claim 1 or claim 2 wherein said pipeline pig has a hollow pressure vessel formed and arranged for securely containing instrumentation for use with said sensing means.

4. An apparatus according to any one of claims 1 to 3 wherein is provided on-board data processing means.

5. An apparatus according to any one of claims 1 to 4 wherein is provided data transmission means for transmitting data obtained from said sensing means to remote data storage and processing means.

6. An apparatus according to any one of claims 1 to 5 wherein said sensing means are selected from the group including:-

- pressure sensing means formed and arranged for measuring the pressure differential across said pig between a leading end and a trailing end thereof;
- velocity sensing means formed and arranged for measuring the velocity of said pig as it passes along a length of pipeline;
- accelerometer means for sensing longitudinal and/or angular acceleration of said pig as it passes along a length of pipeline;
- vibration sensing means;
- noise sensing means;
- temperature sensing means;
- friction sensing means;
- distance measuring means; and
- timing means.

7. An apparatus according to any one of claims 1 to 6 wherein is provided a gyroscope.

8. An apparatus suitable for use in obtaining a substantially continuous debris deposit profile for a length of pipeline which apparatus comprises a debris sensitive pipeline pig provided with sensing means formed and arranged for substantially continuously, directly or indirectly, sensing debris deposits along said pipeline, and data storage means formed and arranged for receiving and storing

debris deposit data from said sensing means thereby to record a substantially continuous debris deposit profile for said length of pipeline.

9. A system for measuring pipeline integrity comprising an apparatus for obtaining a substantially continuous pipeline condition, profile for a length of pipeline; an intelligent pig for measuring pipeline integrity along said length of pipeline; and algorithm means for quantitatively determining the reliability of pipeline integrity data measurements and/or compensating the pipeline integrity data for anomalies resulting from the pipeline condition along said length of pipeline.

10. A method of establishing the integrity of a length of pipeline comprising the steps of:

- obtaining a substantially continuous debris deposit or other pipeline condition profile for said length of pipeline;
- taking measurements at a multiplicity of points along a said length of pipeline using an intelligent pigging process for monitoring the integrity thereof;
- processing said measurements of the integrity of said pipeline with the aid of said substantially continuous debris deposit profile or other pipeline condition profile for at least one of obtaining a reliability profile for the pipeline integrity data and/or compensating the pipeline integrity data for anomalies resulting from the presence of debris deposits or other pipeline conditions along said

length of pipeline.

11. A method of obtaining a substantially continuous debris deposit profile for a length of pipeline comprising the steps of:

- providing a debris deposit sensitive pipeline pig having sensing means for directly or indirectly sensing the presence of debris deposits;
- passing said debris deposit sensitive pipeline pig through a length of pipeline to sense substantially continuous debris deposits therealong; and
- collecting data obtained by said sensing means so as to obtain a substantially continuous debris deposit profile for said length of pipeline.

12. A method a method of obtaining a substantially continuous condition profile for a length of pipeline comprising the steps of:-

- providing a pipeline pig having passive sensing means formed and arranged for sensing the effect of pipeline condition on the passage of said pipeline pig as it passes therealong;
- passing said pipeline pig through a length of pipeline; and
- collecting data obtained by said passive sensing means so as to obtain a pipeline condition profile for said length of pipeline.

13. An apparatus substantially as described hereinbefore and

with reference to Figs. 1, 3 and 4 of the accompanying drawings.

The Patent Office

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Application No:	GB 9620635.4	**Examiner:**	Roger Binding
Claims searched:	1-7	**Date of search:**	27 November 1996

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.O): F2P (PG1)

Int Cl (Ed.6): F16L 55/26, 55/28, 55/40; B08B 9/02, 9/04

Other: Online WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
X	GB 0631988 A (THE SUPERHEATER CO)	1

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.